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EPA's (Environmental Protection Agency's) Incineration of an Industrial Refinery Lagoon Sludge Using Infrared Furnace Technology

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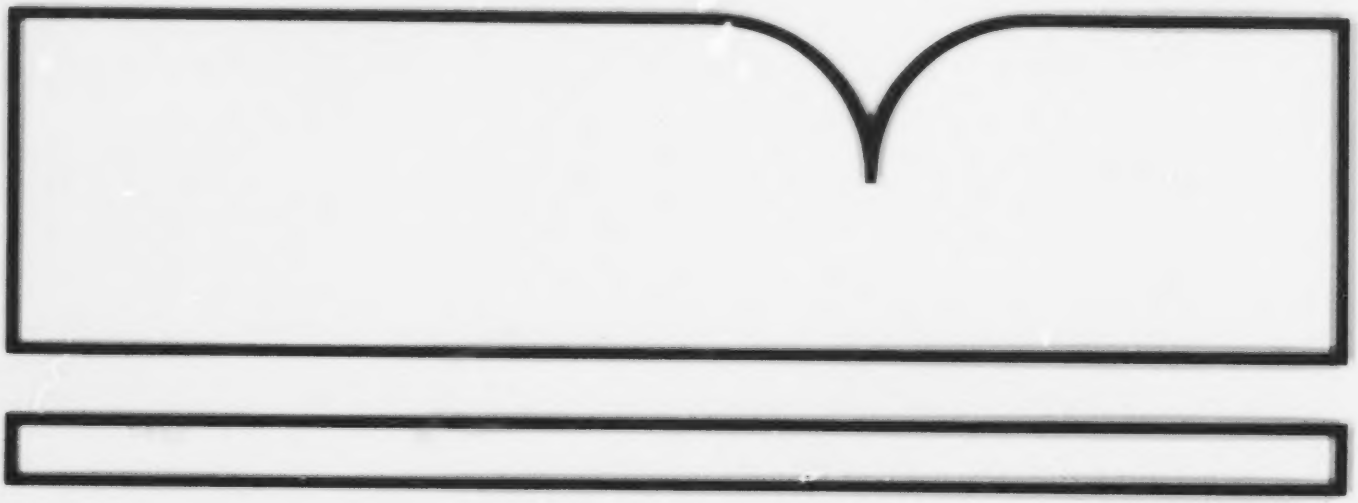

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EPA'S INCINERATION OF AN INDUSTRIAL REFINERY LAGOON SLUDGE USING INFRARED FURNACE TECHNOLOGY

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16 ABSTRACT

This paper briefly presents a case study of a recent field-scale incineration test supported by the U.S. Environmental Protection Agency as one of over twenty projects under EPA's "Superfund Innovative Technology Evaluation" (SITE) program. The purpose of these programs is to encourage demonstration of various innovative techniques for cleaning up polluting hazardous waste sites in different regions of the country. Presented here is an executive summary of the purpose, the technology used, and a summary of the purpose, the technology used, and a summary of performance results of what will be referred to henceforth as the "Peak Oil SITE Cleanup Project."

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a DESCRIPTORS	b IDENTIFIERS/OPEN ENDED TERMS	c COSATI Field/Group

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Abstract

This paper presents results of a recent field-scale incineration test supported by the U.S. Environmental Protection Agency and is one of over twenty projects under EPA's "Superfund Innovative Technology Evaluation" (SITE) program. The purpose of these studies is to evaluate various innovative techniques for cleaning up hazardous waste sites in different regions of the country. Presented here is a summary of the purpose, the technology used, and the performance results of this study, hereafter referred to as the "Peak Oil SITE Demonstration Project."

EPA selected the infrared electric furnace, including an afterburner, to test incineration at a lagoon containing discarded industrial refinery waste from a former waste oil reclamation facility in Brandon, Florida (near Tampa). Action at the lagoon site was determined necessary due to the discovery of pollutants migrating into nearby groundwater from the lagoon's hazardous organics and heavy metals. The primary pollutants in the lagoon were low-level PCBs and lead. However, other toxic organic compounds and heavy metals were also present in low concentrations.

A 100 ton/day infrared incineration system, manufactured by Shirco, Inc., of Dallas, was brought to the site and assembled. The unit was operated to thermally decontaminate the contents of the lagoon. All major performance parameters including the feed stream and all effluent streams were monitored, sampled and analyzed. The results will be reported in a fully detailed project report to be available from EPA at a later date.

Overall, the case study appears to have shown that the basic concept of on-site incineration using an infrared furnace was a workable one. It was found, however, that modifications to the combustion process or air pollution control system

appeared necessary to reduce particulate emissions for future applications of this type. Improvements may also be needed to reduce costs before further applications of this technique will be attractive. Calculations for this particular lagoon clean-up demonstration showed costs between $200 and $800 per ton, depending on whether the down time and the extensive data gathering effort were included in the calculations. A realistic cost appears to be about $400 per ton for projection to similar sites in the future. However, cost estimates of this type are approximate at best because factors such as the economy of scale, waste heating value, and the presence of specific chemicals can play an important role. It is recommended that projection or use of these costs be done very cautiously.

Introduction

Beginning in the 1950's, Peak Oil operated a used oil processing facility at a site on Reeves Road in Brandon, Florida. Various liquid and sludge waste streams from the re-refining operation which included toxic organics and heavy metals were dumped into an existing natural lagoon located on the property. Over time, the lagoon became contaminated with low levels of PCBs, and it was feared that some dioxins and furans might also be present. Due to the area's shallow aquifer systems, the lagoon began to contaminate local groundwater supplies.

The lagoon was not the only source of contamination at this site, but it represented some 7,000 tons (and approproximately the same number of cubic yards) of material. It was judged by EPA to be the most concentrated, accessible, visible, and well defined area of pollution at the site and measured about one quarter to one half of an acre in size.

Summary of Actions Taken:

EPA's Region IV office in Atlanta initiated actions for a cleanup program. The Regional office contracted with the firm of Haztech, Incorporated, an emergency response contractor, to proceed with the cleanup program. EPA's Hazardous Waste Engineering Research Laboratory (HWERL) in Cincinnati, through its Superfund Innovative Technology Evaluation (SITE) program, also participated in the cleanup for this particular lagoon. The HWERL effort primarily involved on-site monitoring and the inclusion of several supplemental sampling and analysis requirements to more completely assess environmental and operating performance of the infrared furnace. These technical services were accomplished through Enviresponse, Inc.

Initial efforts required that the lagoon be drained of water; the remaining sludge was mixed with sand, soil, and lime to form a waste/soil solid matrix that could be handled by earth moving equipment. (The lime, in addition to providing binder to the moisture laden matrix, also counteracted and neutralized the acidic properties of the waste.) This approach greatly facilitated the use of the Shirco Infrared System (with a high temperature afterburner). The SITE demonstration of the Shirco incineration system was carried out between July 31, 1987 and August 5, 1987.

Use of the Shirco System:

The waste/soil matrix was excavated from the lagoon area and screened with a power screen. This device effectively broke up the lumpy waste, blended and aerated the feed, and prepared it for further processing. The screening

system allowed the one inch and smaller clumps to be separated from the rock, roots, and other extraneous material found in the lagoon. From the power screen, the waste feed soil was weighed and conveyed to the Shirco unit.

The Shirco system (see Figure 1) was brought to the site in five individual units consisting of the primary combustion chamber, secondary combustion chamber, air pollution control unit, the stack with various interconnecting ductwork, and a control room unit. Each of these individual units was designed for over-land travel by means of removable wheel assemblies and trailer hitch gear such that they could be hauled as a legal truck-trailer rig over highways. Once on site, the wheel assemblies were removed and the units were field-connected together on suitable poured concrete pads or existing concrete bases to form the complete system. These components were belted together to form: (1) a 67-foot long electric ally heated infrared primary chamber capable of gas temperatures up to 1850°F; (2) a 72 foot long gas-fired secondary combustion chamber (afterburner) capable of reaching temperatures of 2300°F; (3) an emissions control system with a 60 foot tall stack; and (4) a process management and monitoring control center.

The waste soil was conveyor fed into the entrance of Shirco's patented system, the primary infrared furnace. Here the wastes were metered, spread to the proper width, and leveled to optimum process thickness onto a high temperature alloy wire mesh belt which conveyed it through the primary infrared combustion chamber. Waste feed rates ranged from 3.6 to 4.0 tons per hour in this nominal 100 ton per day unit. The waste was exposed to infrared radiant heat provided by horizontal rows of electric powered silicon carbide rods

located above the conveyor belt. Rotary finger rakes were strategically positioned above the conveyor belt and throughout the length of the primary chamber to gently stir the waste for maximum exposure to air and infrared radiation. Typically, the waste was retained on the primary chamber conveyor belt for 18 to 19 minutes. A blower mounted on the primary chamber unit provided combustion air via ducts to strategically located ports in the chamber. Air flow within the chamber was introduced countercurrent to feed material flow. The processed feed material dropped off the end of the belt into a discharge module and was quenched with water sprays prior to being discharged by the screw conveyor system. The ash then exited the primary chamber, without air infiltration, through a screw conveyor that delivered the processed material to an outside receiving container.

Exhaust gases exited the primary combustion chamber through an overhead ceramic-fiber-blanket-insulated-exhaust-duct into the secondary combustion chamber. The secondary combustion chamber provided over 3.0 seconds of residence time, turbulence and supplemental energy to destroy any gaseous organics from the primary furnace. Process heat was supplied by propane gas. The gases leaving the secondary combustion chamber were quenched, particulates were removed in a venturi section, and acid vapor was neutralized in a packed tower scrubber using a sodium hydroxide solution. An induced draft fan drew the cleaned gases from the scrubber into the exhaust stack which was equipped with sample ports. In the event of an emergency shutdown, an emergency bypass stack was located upstream of the quench area. This stack can divert and discharge system gases to atmosphere at a 50-foot elevation; however, this bypass stack was not used at the Peak Oil site.

The system control center contained all process and mechanical controls and monitors, including control panels, emissions monitors, motor control centers, operating personnel, and office space.

With the Shirco unit fully operational at the Peak Oil site, it was the intent of the SITE program to establish reliable performance information in order to evaluate the thermal destruction effectiveness of the unit at this specific site and to evaluate the applicability of the technology to other sites and waste matrices. To this end, an additional contractor, Radian Corporation, was employed to conduct the sampling and analytical phases of the Peak Oil SITE test program.

During a series of 3 replicate test runs, samples of the solid waste feed, liquid streams, furnace ash, and stack gas emissions were obtained under rigorous EPA approved sampling protocols and quality assurance criteria. The most intricate sampling procedures involved the stack gas emissions collection. Sampling methods included a Method 5 train for HCl and particulates, and a Source Assessment Sampling System (SASS) for PCBs, dioxins, furans and semi-volatile priority pollutants. A modified Method 5 train for soluble chromium, a Volatile Organic Sampling Train (VOST) for volatile priority pollutants and various continuous emission monitors for O_2, CO_2, CO, THC, and NO_x were employed. Ambient air monitoring stations were also deployed both upwind and downwind of the unit to monitor any air contamination from the operation of the unit beyond the defined site perimeter.

Complementing the sampling effort, the plant operating data was also monitored and recorded to provide a complete picture of the unit's operation during the 3 replicate SITE demonstration test runs.

Figure 1 shows the overall layout of the incineration system as it was used at the Peak Oil site in Brandon, Florida. The figure also shows the locations where sampling was accomplished.

Waste Feed Characteristics:

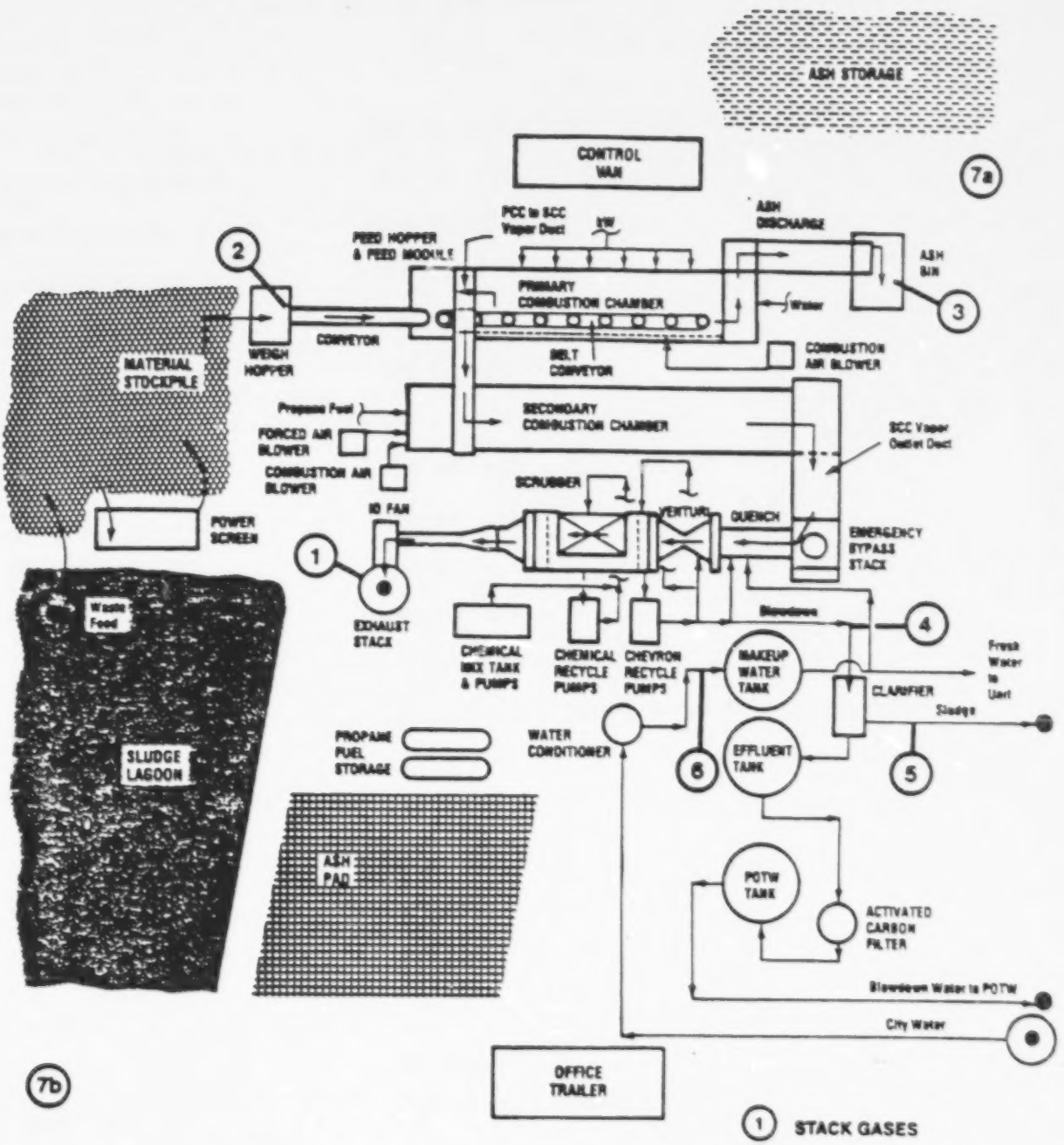
Table 1 shows the typical range of organic and metallic contaminants in the waste feed excavated from the lagoon after the material was blended into a matrix with sand, soil and lime in order to facilitiate its handling. The primary organic of concern was the PCB, while the primary metal of concern was lead. Other characteristics such as heating value and moisture etc. are also shown.

Summary Performance Results:

Presented below is a summary of the results related to each of the objectives for the test program.

° Destruction and Removal Efficiency (DRE)

As shown in Table 2, the unit successfully achieved a DRE in excess of 99.99% for the PCB contaminants, thus satisfying the required RCRA standard. TSCA regulations, which require 99.9999% DRE were not applicable since the contaminated material at the site contained less than 50 ppm of PCBs. Operational temperatures of approproximately 1900°F in the secondary combustion chamber and more than 3 seconds of residence time, instead of the TSCA mandated 2200°F and 2 seconds level, confirmed the unit's satisfactory operation in this situation. Residual PCBs in the ash were below the 1 ppm target level mandated by Region IV thereby achieving one of the most important objectives.



1 STACK GASES
2 SOLID WASTE FEED
3 FURNACE ASH
4 SCRUBBER LIQUID EFFLUENT
5 SCRUBBER SOLIDS
6 SCRUBBER WATER INLET
7a AMBIENT AIR (DOWNWIND)
7b AMBIENT AIR (UPWIND)

FIGURE 1

Sampling Locations Schematic/Layout Diagram Peak Oil Incineration Unit

Waste Feed Solid Matrix Properties

TABLE 1

PCB (Total)	3480 to 5850 micrograms per gram
heptachlorobiphenyl	940 to 2200 " " "
hexachlorobiphenyl	1100 to 1700 " " "
pentachlorobiphenyl	200 to 490 " " "
tetrachlorobiphenyl	440 to 830 " " "
trichlorobiphenyl	570 to 820 " " "
dichlorobiphenyl	120 to 190 " " "
ethyl benzene	40 to 140 " " "
methylene chloride	80 to 120 " " "
toluene	130 to 300 " " "
xylene	280 to 480 " " "
lead content	0.44 to 0.59 percent
antimony	2.1 to 3.6 micrograms per gram
arsenic	2.0 to 2.9 " " "
cadmium	3.9 to 4.6 " " "
chromium	20 to 24 " " "
copper	44 to 55 " " "
strontium	50 to 62 " " "
vanadium	7 to 11 " " "
zinc	950 to 1100 " " "
moisture	14.2 to 16.6 percent
carbon	7.0 to 7.8 percent
sulfur	1.8 to 2.5 percent
chlorine	less than 0.1 percent
ash	70 to 75 percent
Btu value (HHV)	1640 to 2065 Btu/lb

° Particulate Emissions

The Shirco incinerator system at the Peak Oil site demonstrated problems with particulate emissions and failed to meet the regulatory limit of 0.08 grains/dscf at 7 vol. % O_2 as shown in Table 2 except for the third run. Over the three test days that stack gas particulate loadings were measured, the results were 0.1590 grains/dscf (8/1/87) and 0.0939 grains/dscf (8/2/87) and 0.0764 grains/dscf (8/4/86) average. Emission control system modifications and maintenance, after the second test run appear to have been responsible for lowering particulate emissions and eventually meeting RCRA standards in the last two runs.

Interpretation of the data indicates that the inability of the unit's emissions control system to meet particulate emissions requirements was probably due to the lead content in the waste feed and subsequent lead oxide loading at the emissions control equipment.

° Acid Gas Emissions

The emissions of HCl and SO_2 are shown in Table 2. The HCl emissions were relatively low since the chlorine concentration in the waste feed was below the 0.1 weight % detection limit. An actual HCl removal efficiency could therefore not be determined. The more difficult to remove SO_2 constituent was reduced by 99.1 weight %. With sulfur at approximately 2 percent in the waste feed or a sulfur input rate of about 150 pounds per hour, SO_2 emissions were under 2.5 pounds per hour at a maximum measured rate of 1070 g/hr.

° Metals Fixation/Ash Leaching

One of the objectives of this test program was to determine the fate of heavy metal contaminants in the waste feed and whether any metals remaining in the ash were significantly reduced in concentration or would fixate in the ash residue and other solid effluents rendering the ash potentially suitable for delisting as a hazardous waste. The solid waste feed, furnace ash, and scrubber effluent solids were subjected to both the current Toxicity Characteristic Leaching Procedure (TCLP) and the EP Toxicity leaching tests.

The results on the waste feed for both TCLP and EP testing showed that the waste feed exceeded regulatory limits only for lead. The TCLP regulatory limit for lead of 5.0 mg/L was exceeded in one sample of waste feed at 8.8 mg/L, while other samples showed values of 2.5 to 3.5 mg/L. However, the EP regulatory limit (also 5.0 mg/L) was exceeded for lead in the waste feed by larger amounts, namely values of 24.0 to 29.0 mg/L and one sample investigation though not within acceptable spike recovery limits showed 57.0 mg/L. All other metals tested for their TCLP and EP values in the waste feed (eight metals total) were found to be below regulatory levels.

For the ash residue, the results of TCLP and EP testing are summarized in Table 3. Here, TCLP results were lower than regulatory limits in every case. However, the EP results again showed an exceedence for lead which would prevent delisting of the ash residue even though the other metals appeared well below their regulatory limits.

Similarly, for the scrubber water effluent solids, Table 3 shows that again the EP testing values for lead would prevent the material's delisting, while other metals were found to pass the regulatory levels.

Thus, regarding the hoped-for result that lead and other heavy metals would somehow be inactivated by some process of conversion into non-leachable organic or inorganic complex compounds, of which the primary metal of concern was lead, was not met.

° Organics in Ash or Scrubber Effluent Solids

TCLP testing for organic materials other than PCB was done on waste feed, the ash residue, and the scrubber solid samples. The results, which involved testing for some 36 organic hazardous compounds, will be reported in EPA's final report. However, other than those compounds reported in Table 1 for the waste feed material, all 36 compounds were generally found to be either non-detectable or far below any regulatory levels for TCLP.

° Metals Emissions from Stack:

The largest mass release of metals measured in the stack emissions was that of lead. The specific amounts varied from a release of 2000 grams per hour of lead for the first test run on 8/1/87 down to a range of 780-1000 grams per hour of lead in subsequent runs where changes were made to the operation of the pollution control system. It is interesting to note that the calculated net input feed rate of lead from the waste ranged between 17,000 to 19,000 grams per hour for the test runs made. Thus, the amount of lead exiting the stack represented

TABLE 2

Stack Emissions Data

Date of Run	DRE for PCB (percent)	Particulates Grains/DSCF @ 7% O_2	HCl in g/hr	SO_2 in g/hr
8/1/87	99.99967	0.1590	<0.8	27.4
8/2/87	99.9988	0.0939	8.6	1070.0
8/3/87	99.99972			
8/4/87	99.99905	0.0768	2.9	22.0
8/4/87 (Duplicate)		0.0761	2.7	20.6

TABLE 3

Leaching Test Results

Metal	Regulatory Level mg/L	Ash EP Toxicity avg. mg/L	Ash TCLP Test avg. mg/L	Scrubber Effluent Solids EP Test avg. mg/L	Scrubber Effluent Solids TCLP Test avg. mg/L
Arsenic	5.0	0.020	0.007	ND	<.22
Barium	100	1.35	0.25	<.56	<.80
Cadmium	1.0	0.98	0.008	0.5 - 1.9	<.22
Chromium	5.0	0.57	0.037	<.65	<.08
Lead	5.0	31	0.011	3.1 - 40.0	.12 - .38
Mercury	0.2	0.0015	ND	ND	ND
Selenium	1.0	ND	0.031	ND	ND
Silver	5.0	0.031	0.059	<.04	<.06

ND = not detectable

about 11.2% of the feed rate of lead for the first run and between 4.2 to 5.5% of the feed rate of lead for subsequent runs. Also, it should be noted that lead (or lead compounds) represented 54 to 60% of the mass of particulates from the stack.

In total, 30 different metals were sampled for and analyzed in the stack particulate material. Other than lead, the next highest amounts of metals emitted as particulate were measured to be zinc (16-17 grams per hour), sodium (31-34 grams per hour), and chromium (0.51 - 0.53 grams per hour). Stack sampling and analysis for chromium VI concentrations yielded results of less than 160 micrograms per cubic meter.

A listing of the data for metals is presented in Table 4. Presented here are 11 metals in terms of their levels in the waste feed, in the ash residue, and finally their levels emitted via the stack gas particulate material. The remaining 19 metal species were not shown in this summary table because of either their low levels found or because they were not particularly toxic, but their levels will be reported in the final report.

° Dioxins and Furans

Since PCB was in the waste, it was required to investigate whether there may have been any signficant levels of dioxins and/or furans in the lagoon and thus in the waste matrix processed by the Shirco system. Sampling and analysis for these compounds was conducted for the waste matrix, the ash, the scrubber waters, scrubber solids, and the stack gas.

All of the above analyses resulted in less-than-detectable levels of these compounds as summarized below for TCDD, TCDF, PCDD, and PCDF:

Sample	TCDD	PCDD	TCDF	PCDF	Detection Limit
waste feed matrix:	ND	ND	ND	ND	1.1 ppb
ash after treatment:	ND	ND	ND	ND	1.4 ppb
scrubber water:	ND	ND	ND	ND	0.002 nanograms per liter
stack gas:	ND	ND	0.47*	ND	0.34 micrograms per cubic meter

* reported for one test out of 4 tests

° Cost/Economic Analysis:

The economic analysis concluded from current cost figures of this Shirco transportable infrared incineration system that the estimated incineration costs might be as low as $196 per ton for an operation at an 80% on-stream capacity factor. Actual costs might approach $795 per ton for the overall operation at the Peak Oil site at a 19% on-stream capacity factor. As a current basis for projection, these authors suggest that a $400 per ton cost figure might be considered to be a realistic, near-term cost achievement, but again as stated in the summary, we would caution the user that each specific site should be evaluated with care because of potential impacts of size, location, the types of pollutants, and so on.

Outlook for the Future:

This was the first "full or field-scale" operation of the Shirco Infrared System and the system worked reasonably well under the circumstances. However, the feed preparation system, which must provide less-than-one-inch particle sizes to the infrared chamber, must be recognized as being very important. Although the air pollution control system used in the Peak Oil test was "marginal" in terms of handling the high fines and lead content. These heavy concentrations of lead may not exist in the feed at other burn

TABLE 4

Metals Analysis

Parameter	Solid Waste Feed micrograms per gram	Ash micrograms per gram	Average Stack Emission Rate grams/hr
Antimony	2.15	3.3	.13
Arsenic	2.55	2.6	.065
Cadmium	4.15	4.1	3.4
Chromium	22	27	.54
Copper	49	64	.37
Lead	4800	6400	1150
Mercury	ND	ND	ND
Sodium	5550	5600	33
Strontium	57	76	.017
Vanadium	9	13	<.036
Zinc	1030	1060	16

ND = not determined

clean-up locations and it is believed that improved technology to reduce the emissions is available as state of the art and should be used, if necessary, for any further applications. For example, a high efficiency fabric filter could be employed at sites with similar particulate emissions concentrations. Also, the use of electric energy could be reduced in future applications through the blending of fossil fuel(s) with the waste feed matrix.

The equipment as it was used at the Peak Oil site had the ability to adequately control the "roasting" time and other conditions such as oxygen and temperature on the belt and in the primary infrared chamber. The after-burner also performed well in terms of providing additional burnout of organics, temperature, and additional residence time, etc.

Finally, the Shirco unit's design as a transportable, modular, field-assembled and disassembled unit appears to have been successful for its intended purpose in this test case.

Final Report Status and Acknowledgements:

As noted earlier, the results presented herein represent an overview or summary of the significant results of the Peak Oil SITE Demonstration Project, and the fully detailed project description with all reviewed and final performance results will be reported shortly. At this jucture, EPA project personnel are in the process of reviewing a report entitled:

Draft: Technology Evaluation Report, SITE Program Demonstration Test, Shirco Infrared Incinerator System, Peak Oil, Brandon, Florida, December 1987, EPA Contract No. 68-03-3255.

It is currently anticipated that the draft final report should be ready for publication sometime in early to mid-1988.

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